Directed Logic WDM-Based Scalable Optical Decoder Using Micro-Ring Resonators

Rohan Mital[1], Zhoufeng Ying[1], Chenghao Feng[1] and Ray T. Chen[1*]
[1]Microelectronics Research Center, Department of Electrical and Computer Engineering, University of Texas
Austin, TX 78758 USA
*Email: chenrt@austin.utexas.edu

***Abstract*— A novel design for an optical decoder is demonstrated in which by using the Wavelength-Division Multiplexing (WDM) property of the micro-ring resonators, we greatly simplify the design and achieve scalability to produce N-bit decoders. We designed the decoder logic using directed logic. Directed logic takes the full advantage of integrated photonics and electronics and has received lots of investigation since its introduction. The feasibility of the proposed decoder is verified through simulation.**

I. INTRODUCTION

Directed logic is designed to take full advantage of the optical domain which can be used to build traditional combinational logic circuits [1]. Electrical signals are used to modulate light that is guided along various optical components to get the desired output. The advantage of directed logic is that as all the electrical signals are simultaneously provided, we get lower latency in the design as compared to electrical combinational logic where the delay is cascaded [2]. So far, complex logic devices such as encoders, comparators and adders have been demonstrated using directed logic [3]. In [4], Tian Yonghui et. al. have proposed a directed logic optical decoder consisting of micro-ring resonators but their design is not scalable to build N-bit decoder circuits.

In this paper, a novel directed logic optical decoder design based on wavelength-division multiplexing (WDM) is presented. In WDM, we choose two wavelengths from the same spectrum of the micro-ring resonator such that we can get negation of the logic from the same electrical signal. This facilitates scalability to build N-bit decoder circuits.

II. PROPOSED WDM-BASED OPTICAL DECODER

Proposed Optical Decoder is based on WDM. For a resonator-based modulator, the applied voltage changes the refractive index of the cavity through carrier dispersion effect or thermal-optic effect [5] and then the spectrum shifts as shown in Fig 1. In the figure, P represents light coming in and a is the electrical signal which modulates P by shifting the spectrum of the micro-ring resonator. Y is the output which represents the input light P modulated by the electrical signal a or negation of a depending on the wavelength of P. If we put micro-ring resonators with different electrical signals along the branch, light gets modulated by each electrical signal independently which is identical to series of AND operation in combinational logic. Using this cascading property and negation from WDM, we designed the 3-to-8 optical decoder shown in Fig. 2 along with the logical outputs when using λ_1 or λ_2 from the continuous wave (CW) laser.

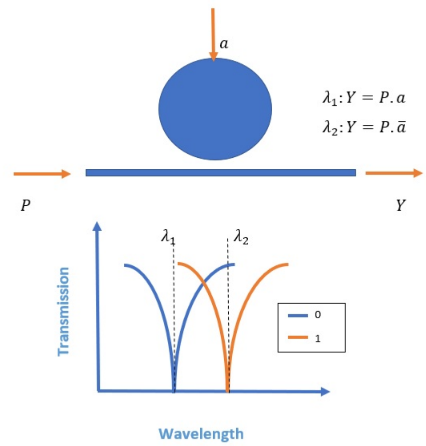

Fig. 1. Modulation of input light P using electrical signal a and the output Y for two different wavelengths λ_1 and λ_2

This scheme considerably simplifies the directed logic design and reduces the number of micro-ring resonators required for the decoder by exactly half. This is a clear advantage over its electrical counterpart. For instance, a 3-bit decoder requires 8 outputs, but the optical decoder will give the same result using only 4 outputs as we can get all the logical outputs by changing the wavelength of the source. One of the major advantages of this design is its scalability. We can easily design a larger bit decoder by extending the decoder using splitters to divide the input signal equally into two branches. Each branch is then connected to micro-ring resonators which are identical to the previous ring resonator as shown in Fig 3.

III. RESULT AND DISCUSSION

In Table I, we have the truth table for a 3-to-8 decoder. We have compared the output of our 3-to-8 optical decoder with that of a conventional 3-to-8 electrical decoder in Fig. 4. We observed that we got the same results as well as correct logical outputs which match our truth table in Table I. We observe some peaks in the output of the optical decoder. We used a high frequency non-return-to-zero (NRZ) signal

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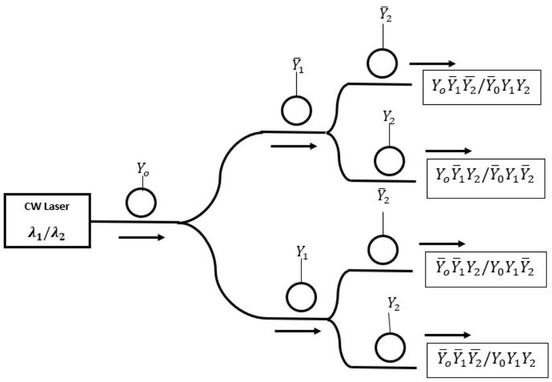

Fig. 2. Proposed 3-to-8 optical decoder using WDM

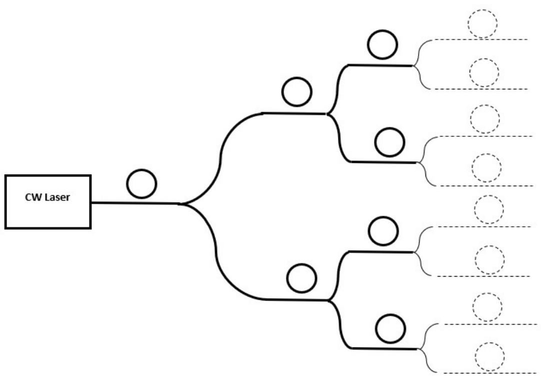

Fig. 3. Demonstration of the scalability of the decoder by simply adding micro-ring resonators and splitters

TABLE I
TRUTH TABLE OF 3-TO-8 DECODER

Y_0	Y_1	Y_2	D_0	D_1	D_2	D_3	D_4	D_5	D_6	D_7
0	0	0	1	0	0	0	0	0	0	0
0	0	1	0	1	0	0	0	0	0	0
0	1	0	0	0	1	0	0	0	0	0
0	1	1	0	0	0	1	0	0	0	0
1	0	0	0	0	0	0	1	0	0	0
1	0	1	0	0	0	0	0	1	0	0
1	1	0	0	0	0	0	0	0	1	0
1	1	1	0	0	0	0	0	0	0	1

to generate the output of the decoder. The spectrum of the micro-ring resonators cannot suppress the high frequency harmonics of the NRZ signal which leads to slight distortion in the output signal.

IV. CONCLUSION

In this paper, a scalable optical decoder design was presented using directed logic and WDM. The results verify the feasibility of our design and makes a strong case for future practical implementation. The optical decoder we propose is highly scalable and can be easily extended to perform decoding of larger bits or codewords.

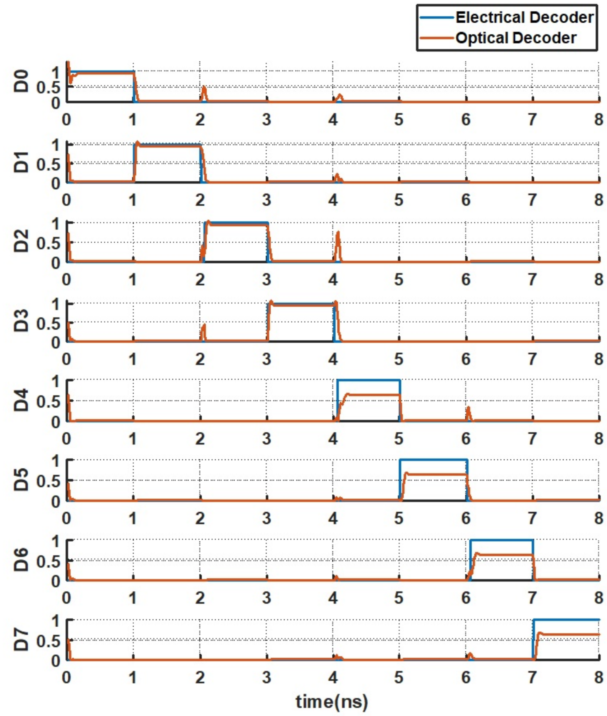

Fig. 4. Output signal of 3-to-8 optical decoder at 1Gb/s

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